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Tensile strength of polyester resin reinforced sugarcane bagasse fibers modified by estherification

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Abstract

In the present work, chemical modification of the sugarcane bagasse fibers by estherification through anhydride system was studied to use as reinforcement in polyester matrix. Sugarcane bagasse fibers were estherified during 5 hours with acetic anhydride, toluene, acetic acid and percloric acid. The modification the fibers were evaluated by techniques scanning electron microscope (SEM) and X-ray diffractometry (XRD). Furthermore, fibers were mixed with the polyester resin and compression molding, in which fibers were responsible for 5 wt% in the composition. After that, the composite was left to cure at room temperature for 24 hours and machined into specimens of according to ASTM D-3039 specification. Tensile tests were carried out using EMIC machine according to ASTM D3039. Results relieved that composites presented better mechanical strength when compared to pure polymer, which exhibited an increase de 71.5% compared to the pure polymer.

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Keywords: Sugarcane bagasse; Interfacial bonding; Mechanical properties

1. Introduction

New environmental legislation as well as consumer pressure has forced manufacturing industries to search new materials. Because of this, in the years the use of natural fibers as reinforcement in thermoplastic and thermosetting matrices has generated much interest, due to their low cost, low density, biodegradability, renewability and abundance.

Natural fibers have different origins such as wood, pulp, cotton, bark, bagasse, bamboo, cereal straw, and vegetable (e.g., flax, jute, hemp, sisal, and ramie) [1,2]. These fibers are mainly made of cellulose,

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hemicelluloses, lignin and pectins, with a small quantity of extractives [3]. Compared to glass fiber and carbon fibers, natural fibers provide many advantages, such as, abundance and low cost, biodegradability, flexibility during processing and less resulting machine wear, minimal health hazards, low density, desirable fiber aspect ratio, and relatively high tensile and flexural modulus.[4] Incorporating the tough and light-weight natural fibers into polymer (thermoplastic and thermosetting) matrices produces composites with a high specific stiffness and strength [5, 6].

However some drawbacks, such as the incompatibility between fibers and polymer matrices, the tendency to form aggregates during processing and the poor resistance to moisture, reduce the use of natural fibers as reinforcements in polymers [7,8]. Several chemical modifications and chemical coupling agents are considered to optimize the interface of fibers.

In general, chemical coupling agents are molecules possessing two functions. The first function is to react with hydroxyl groups of cellulose and the second is to react with functional groups of the matrix [9-10]. The moisture absorbed by the fibres can be reduced by chemical modifications of fibers such as acetylation, mercerization, methylation, cyanoethylation, benzoylation, permanganate treatment, acrylation and estherification [11-13].

Of this way, the objective of this work was available the effect of the modified sugarcane bagasse fibers by estherification through anhydride system on mechanical properties polyester resin reinforced modified sugarcane bagasse fibers composites. The modification the fibers were evaluated by techniques scanning electron microscope (SEM) and X-ray diffractometry (XRD).

2. Experimental

2.1. Fibers

The fibers used in this study were manufactured by Edras Ecosistema. Chemical modification of the sugarcane bagasse fibers by estherification through anhydride system was studied to use as reinforcement in polyester matrix. Sugarcane bagasse fibers were estherified for 5 hours with acetic anhydride, toluene, acetic acid and percloric acid.

2.2. Scanning electron microscopy

SEM was used to investigate the microstructure and the surface morphology of modified and unmodified sugarcane bagasse fibers. Samples were mounted on conductive adhesive tape and coated with gold using an ion sputter and observed with a Jeol JSM 5310 microscope operated at 15 kV.

2.3. X-ray analysis

XRD measurements were performed on a Shimadzu diffractrometer model XRD6000. The diffracted intensity of CuKα radiation (0.154 nm, 30 kV and 40 mA) was measured in a 2θ range between 10^{o} and 40^{o}. The sugarcane bagasse samples (modified and unmodified) were subjected to crystallinity analysis.

2.4. Composites preparation

The composites were manufacture in a glass mould (250 mm x 250 mm). For the preparation of composites were used: polyester resin and modified and unmodified sugarcane bagasse fibers. The composites were prepared by compression molding. The components of the polyester resin were mixed

manually. Furthermore, the fibers were added. The concentration of fibers added was 5 wt% of the final mass of the pure polymer (polyester resin). After the cure, around 24 hours, the material was removed from the mold and was submitted to the tensile tests. It was also prepared the polyester matrix without the addition of sugarcane bagasse reinforcements. All the process was performed at room temperature.

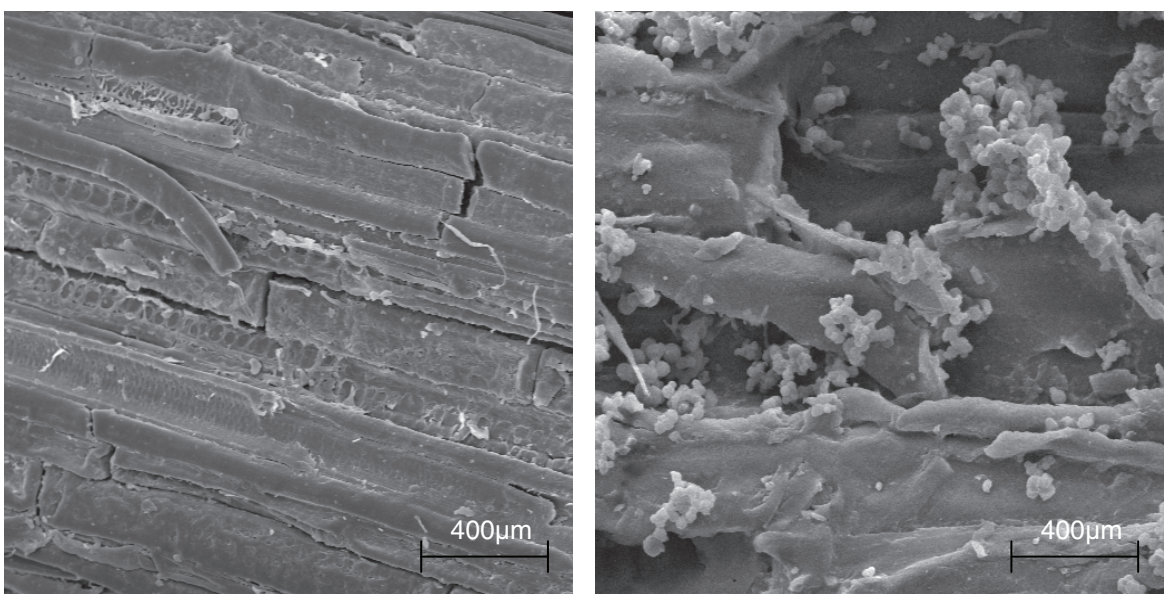
2.5. Mechanical properties

The mechanical strength of modified sugarcane bagasse fibers reinforced polyester resin composites was determined using an EMIC DL2000 universal testing machine. Tests were carried out according to ASTM standards D3039 with 2 $mm.min^{-1}$ crosshead speed. Tensile strength and modulus values are average results of five tested specimens for each type of composite.

3. Results

3.1. Scanning electron microscopy (SEM)

The surface morphology of the sugarcane bagasse fibers was studied by scanning electron microscopy (SEM). Figure 1(A) present SEM micrographs of unmodified sugarcane bagasse fibers, which evidence a large amount of extractives. However, after the modification on sugarcane bagasse fibers was observed the removal of the extractives on surface fibers as can be observed in the Figure 1(B). It was verified also that with the elimination of superficial layer the contact area and the presence of materials dispersed on fibers caused by modification. As a consequence, it is observed an increase in the roughness of fibers, which can contribute with the increase of the interfacial bonding between fibers and matrix.



(A) (B)

Figure 1. Morphology of sugarcane bagasse fibers: (A) unmodified; (B) modified.

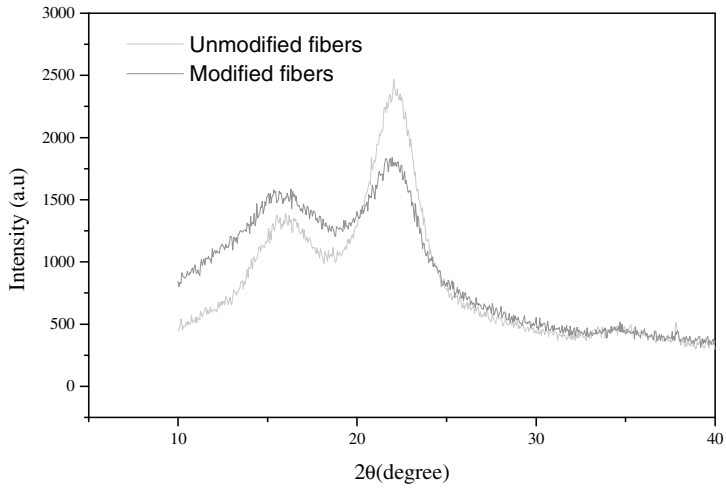


Figure 2. X-ray diffractogram of the sugarcane bagasse fibers (modified and unmodified).

3.2. X-ray diffraction (XRD)

Figure 2 show the X-ray diffractogram of sugarcane bagasse fibers. It presents two peaks, which are well defined. X-ray diffraction peaks for both materials can be attributed to crystallinity scattering and the diffuse background to disordered regions. Materials tested are semicrystalline.

Spectrum corresponding to the unmodified fibers shows diffraction peaks at the following 2θ angles: 15.9º and 22.0º. The fibers modified the same peaks can be observed at 15.9º and 22.2º. The presence of the peaks at 15º and 22º are an evidence of the modification on fibers. The position of these peaks indicates an increase of the interplanar distance compared to the modified fibers. This behavior occurs due to the generation of disorder when fibers are modified [14]. Patterns for both materials are similar, however modified fibers are less crystalline compared to the modified one.

3.3. Mechanical Properties

Mechanical properties of the composite and pure polyester are summarized in Table 1.

Table 1. Mechanical properties of the materials

Materials	Tensile strength (MPa)	Tensile modulus (MPa)
Polyester resin	19.7 ± 0.6	894.3 ± 29.5
Unmodified sugarcane bagasse fibers (5%)/ polyester	11 ± 0.001	1358.1 ± 0.02
Modified sugarcane bagasse fibers (5%)/ polyester	12.5 ± 2.2	1534.1 ± 86.6

Reinforcement in wt%.

Pure polymer presented higher tensile strength results compared to the composites reinforced with sugarcane bagasse fibers (unmodified and modified). However, it was observed a difference minimal between composites in tensile strength. On the other hand, analysing tensile modulus the composites presented higher tensile modulus when compared to the pure polymer. This occurred due to good

interaction between fibers and matrix. Fibers insertion can contribute to the modulus increase, which exhibited an increase of 71.5%, compared to the polyester resin.

However, composites reinforced with modified fibers presented higher tensile modulus compared to the composites reinforced with unmodified fibers, exhibiting an increase of 13%.

3. Conclusions

This study suggests that modified sugarcane bagasse fibers are potentially attractive for reinforcing in thermosetting polymer. Chemical modification of the sugarcane bagasse fibers was studied to demonstrate the effect of modification on the mechanical properties of the composites and to study the practicability of processing these fibers with thermosetting. The modification in sugarcane bagasse fibers revealed an improving in the tensile modulus in comparison to the polymer pure, exhibiting an increase of 71.5%. This fact occurred due to the treatment made on fibers, which can have facilitated the interfacial bonding. Scanning electron microscopy and X-ray diffraction techniques demonstrate the effect of modification on fibers.

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